The Road Ahead for Autonomous Vehicles

S&P’s View on AV Implementation and Potential Credit Impacts

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U.S. Public Finance

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Agenda

AV 101: How We Got Here

S&P Global Ratings’ View Of AV Implementation

Autonomous Vehicles & the Key Credit Impacts on Various Sectors
Growth of fully autonomous vehicles will be influenced by and will lag the growth of electric vehicles.

Under our low disruption scenario advanced autonomous vehicles requiring minimal to no driver intervention could reach a 2% share of light vehicle sales by 2030 rising to 10% by 2040.

The trajectory of autonomous vehicle growth is complex and unpredictable as it faces hurdles beyond technology and cost.

If autonomous vehicles and related technology mobility advances develop incrementally and linearly with current industry participants leading the way, we anticipate fewer positive or negative credit implications.

Source: The Stack.
AV 101: How We Got Here

States With Enacted Autonomous Vehicle Legislation
Over half of U.S. states have cleared the way for some type of autonomous vehicle legislation

30+
U.S. states have enacted laws and executive orders related to advancing AV technology*

$80 billion
AV investments between August 2014 and June 2017
What Might Slow Down AV Growth?
AV growth faces many hurdles beyond technology and cost. AV adoption across the globe will be slow and fragmented based on these hurdles.

Which Country Will take the Lead in AV Implementation?
We expect China to seize leadership in development and implementation.

Our low-medium-high disruption scenarios for the U.S.
We have developed three SAE level 4 and level 5 AV disruption scenarios for the U.S. – low, medium, and high
AV Adoption Faces Many Barriers And Uncertainties

Regulatory developments are likely to advance faster in the U.S. and China, while being delayed in Europe.

Incidents such as fatalities will hurt the technology's image in consumers' minds and lead to a push for more federal and state regulations.

FMI research estimates that due to decreased traffic congestion from AVs, slightly more than $13 billion in motor fuel taxes could be lost.

The NHTSA estimates human error causes ~94% of accidents and 35,000 fatalities a year, but AVs will require significant insurance policy development.

Source: Semiconductor Engineering; Colorado The Official State Web Portal (codot.gov); The Sacramento Bee.
## Low Disruption Scenario

### Assumptions Behind AV Implementation in U.S.

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Phase I: 2020-2030</th>
<th>Phase II: 2030-2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated 2017 U.S. Car Fleet size</td>
<td>270 million at end of 2017</td>
<td></td>
</tr>
<tr>
<td>Average annual Light Vehicle sales and growth forecast (2020 – 2040)</td>
<td>About 16.7 mill or about 1% annual growth rate</td>
<td></td>
</tr>
<tr>
<td>Scrappage rate (annual vehicles retired from use as a % of light vehicle sales)</td>
<td>Steady at around the last four years (~70%) and no government incentives for AVs</td>
<td></td>
</tr>
<tr>
<td><strong>AV Technology</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Safe &amp; Reliable Tech Advancement</td>
<td>Incomplete to slow</td>
<td>Gradual</td>
</tr>
<tr>
<td>- AV Price premium reduction/cost savings from lower fuel costs or insurance</td>
<td>Very Expensive or significant cost savings due to nascent technology, no government incentives, and high insurance costs</td>
<td>Expensive</td>
</tr>
<tr>
<td>- Government Incentives</td>
<td>None</td>
<td>Low to Moderate</td>
</tr>
<tr>
<td>- EV technology growth and adoption</td>
<td>Low</td>
<td>Slow to Moderate</td>
</tr>
<tr>
<td><strong>Govnt/Insurance Regulation &amp; Policies, &amp; Related Infrastructure Development</strong></td>
<td>Slow/Delay</td>
<td>Gradual/moderate</td>
</tr>
<tr>
<td>Growth in ride/car sharing</td>
<td>Low to Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Consumer Acceptance</td>
<td>Limited</td>
<td>Limited to Moderate</td>
</tr>
<tr>
<td>Resultant AV Share of Light Vehicles Sales (adoption rate) by 2030 (%)</td>
<td>~2%</td>
<td>~10%</td>
</tr>
<tr>
<td>Resultant AV Fleet Share of US Car Fleet by 2030 (%)</td>
<td>&lt;1%</td>
<td>&lt;5%</td>
</tr>
</tbody>
</table>
## Medium Disruption Scenario

### Assumptions Behind AV implementation in U.S.

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Phase I: 2020-2030</th>
<th>Phase II: 2030-2040</th>
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<tr>
<td>Scrappage rate (annual vehicles retired from use as a % of light vehicle sales)</td>
<td>82% based on historical average since 1990</td>
<td></td>
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<tr>
<td><strong>AV Technology</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Safe &amp; Reliable Tech Advancement</td>
<td>Gradual; accelerated towards the end of the decade</td>
<td>Fast and Complete</td>
</tr>
<tr>
<td>- AV Price premium reduction/cost savings from lower fuel costs or insurance</td>
<td>Expensive with gradual decline in AV prices, low government incentives, and high insurance costs</td>
<td>Declining premium/improving cost savings</td>
</tr>
<tr>
<td>- Government Incentives</td>
<td>Low</td>
<td>Moderate to High</td>
</tr>
<tr>
<td>- EV technology growth and adoption</td>
<td>Moderate</td>
<td>Accelerated</td>
</tr>
<tr>
<td><strong>Govt/Insurance Regulation &amp; Policies, &amp; Related Infrastructure Development</strong></td>
<td>Gradual/moderate</td>
<td>Accelerated</td>
</tr>
<tr>
<td>Growth in ride/car sharing</td>
<td>Moderate to High</td>
<td>High</td>
</tr>
<tr>
<td>Consumer Acceptance</td>
<td>Moderate</td>
<td>Moderate to High</td>
</tr>
<tr>
<td>Resultant AV Share of Light Vehicles Sales (adoption rate) by 2030 (%)</td>
<td>~15%</td>
<td>~30%</td>
</tr>
<tr>
<td>Resultant AV Fleet Share of US Car Fleet by 2030 (%)</td>
<td>&lt;5%</td>
<td>&lt;15%</td>
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</tbody>
</table>
# High Disruption Scenario

## Assumptions Behind AV Implementation in U.S.

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<td>About 16.7 mill or about 1% annual growth rate</td>
<td></td>
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<tr>
<td>Scrappage rate (annual vehicles retired from use as a % of light vehicle sales)</td>
<td>Accelerated due to substantial government incentives for AVs; 95%</td>
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</tbody>
</table>

### AV Technology

- **Safe & Reliable Tech Advancement**
  - Fast and Complete

- **AV Price premium reduction/cost savings from lower fuel costs or insurance**
  - Marginal Premium with rapid decline in AV prices, high government incentives, & lower fuel & insurance costs

- **Government Incentives**
  - High

- **EV technology growth and adoption**
  - High

**Govnt/Insurance Regulation & Policies, & Related Infrastructure Development**

- **Accelerated**

### Growth in ride/car sharing

- **High to Significant**

### Consumer Acceptance

- **High**

### Resultant AV Share of Light Vehicles Sales (adoption rate) by 2030 (%)

- **~30%**
  - **~50%**

### Resultant AV Fleet Share of US Car Fleet by 2030 (%)

- **<10%**
  - **<35%**
Autonomous Vehicle Adoption Rate Forecast (2020 – 2040)

AV Share Of Total U.S. Fleet

<table>
<thead>
<tr>
<th>Year</th>
<th>Phase 1 Growth Factor</th>
<th>Phase 2 Growth Factor</th>
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<tbody>
<tr>
<td>2020</td>
<td></td>
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<tr>
<td>2021</td>
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<td>2040</td>
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</tbody>
</table>

- **High Disruption**: 1.41x, 1.05x
- **Medium Disruption**: 1.31x, 1.07x
- **Low Disruption**: 1.15x, 1.22x
<table>
<thead>
<tr>
<th>Sector</th>
<th>Key Credit Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automakers &amp; Suppliers</td>
<td>• No meaningful impact as deployment of AVs is several decades away</td>
</tr>
<tr>
<td>Insurance</td>
<td>• Shifting liability from individuals to auto manufacturers</td>
</tr>
<tr>
<td></td>
<td>• Impacts of crash avoidance technology</td>
</tr>
<tr>
<td>Electric Utilities &amp; Oil Companies</td>
<td>• Growth opportunities for utilities pursuing EVs</td>
</tr>
<tr>
<td></td>
<td>• Oil Industry losing market share to electric utilities</td>
</tr>
<tr>
<td>Infrastructure Transportation</td>
<td>• Private and Public Transportation issuers</td>
</tr>
<tr>
<td></td>
<td>• Toll roads, airports and parking</td>
</tr>
</tbody>
</table>
Global Auto Industry 2018: At A Crossroad

- Global automotive demand is likely to remain stable through 2017 and into 2018, roughly in line with our prior expectations and varying by region.

- We expect ratings on automakers and suppliers to remain generally stable, with little upside, particularly in the U.S. and Europe.

- Powertrain electrification is likely to be the most important disruptive mega-trend in the next decade, in our view.

- Autonomous driving and new mobility services could over time challenge the business models of incumbent manufacturers and suppliers.

- Partnerships between automakers and suppliers as well as alliances and restructurings will become more common and vital to all companies' efforts to stay competitive.
Crash Avoidance Technology’s Impact On Motor Insurers

- Human Error causes 90% of accidents
- Declines in frequency and severity of claims
- Drop in claims means a fall in premium rates
- Diversification of Retail Insurance Product Portfolio
- Barriers providing sufficient time to adjust business models
- Delayed Impacts to U.K. Motor Insurance Market

Source: BLG
EVs Electric Utilities and Oil Companies Compete for Market Share

EVs and Potential Opportunities for Electric Utilities
- Lower-cost batteries - potential opportunity and revenue growth.
- Utility-scale battery storage & increasing need for electric charging stations - a new capital spending opportunity
- Increasing popularity of electric vehicles - modest increase to the utility industry’s total electric sales.

Oil, Utilities Fight to Fuel Vehicles of the Future
Saudi Arabian Oil Co., trying to protect its market share by making engines more efficient.

• In the U.S., EVs could help double, or nearly triple, annual growth rates for power demand over the next three decades.
• Concern in the oil industry as about one-quarter of all oil is used to make gasoline. Big Oil could be left with idled refining capacity and too much crude, which would lower prices.

### Possible Impacts for Infrastructure Assets
(assuming transition to full adoption)

<table>
<thead>
<tr>
<th>Category</th>
<th>Impact Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle Miles Travelled</strong></td>
<td>Increased convenience induces demand from current non-drivers and substitution from other transportation. 5% to 20% increase in VMT when AV market penetration reaches 50%</td>
</tr>
<tr>
<td><strong>Congestion</strong></td>
<td>Increased trip-making and with more miles traveled</td>
</tr>
<tr>
<td><strong>Parking Requirements</strong></td>
<td>Increased car sharing can reduced need for on-site parking</td>
</tr>
<tr>
<td><strong>Public Transport</strong></td>
<td>Displace passenger rail and air travel between short haul destinations</td>
</tr>
<tr>
<td><strong>Road Lifecycle</strong></td>
<td>Increased volume of traffic and greater wear due to more commercial vehicles. Smoother braking &amp; acceleration of AVs could potentially offset the additional roadway wear</td>
</tr>
</tbody>
</table>
Autonomous Vehicles Preliminary Views

**Toll Roads**
Potential Winner

- Higher VMT due to increased mobility from current non-drivers coupled with an aging population (+)
- Fewer road delays due to safer highway travel (+)
- Increased carrying capacity due to more efficient driving patterns (+)

**Parking Garages & Airports**
Potential Loser

- Reduced personal vehicle ownership (-)
- Increased car-sharing (-)
- Reduced need for on-site parking(-)
- Development of new areas / land for off-site parking, maintenance and storage of fleet-wide AVs (+)

*We are not currently rating to this view on winners and losers (which assumes full automation which is a ways off). But we expect to begin to incorporate stress scenarios into our financial forecast analysis to assess asset resiliency.*

Source: Autonomous Vehicle Test & Development Symposium
Autonomous Vehicles Preliminary Views

Fluidity of factors on pooling and AV makes predictions uncertain*

Transit & Managed Lanes with Trucks
Uncertain
• Revival of commercial trucking industry due to AV technology (+)
• Increased lane throughput due to platooning (+)
• Smart-car technology may improve electronic-toll collection methods (+)
• Reduced congestion due to increased off-peak and over-night driving (-)
• Greater road wear and tear (-)

Managed Lanes with Free HOV but No Trucks
Uncertain
• Development of dedicated lanes for AVs (+)
• Increased carrying capacity in non-managed lanes (-)
• Reduction in revenues due to free lane usage for HOVs (-)
• Reduced congestion due to increased off-peak and over-night driving (-)
• Reduced vehicles on the road due to pooling (-)

Source: Transurban.
Key Takeaways

1. Growth of fully autonomous vehicles will be influenced by and will lag the growth of electric vehicles.

2. Under our low disruption scenario advanced autonomous vehicles requiring minimal to no driver intervention could reach a 2% share of light vehicle sales by 2030 rising to 10% by 2040.

3. The trajectory of autonomous vehicle growth is complex and unpredictable as it faces hurdles beyond technology and cost.

4. If autonomous vehicles and related technology mobility advances develop incrementally and linearly with current industry participants leading the way, we anticipate fewer positive or negative credit implications.

Source: The Stack
Kurt Forsgren
Managing Director and Sector Leader
Transportation Ratings

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Automated and Autonomous Vehicles: The SAE Scale

**Society Of Automotive Engineers’ Five Levels Of Automation**

<table>
<thead>
<tr>
<th>Level</th>
<th>Steering and acceleration/deceleration</th>
<th>Monitoring of driving environment</th>
<th>Fallback when automation fails</th>
<th>Automated system is in control</th>
<th>Example of driver roles</th>
<th>Example vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>![Image of Level 0]</td>
<td>![Image of Level 0]</td>
<td>![Image of Level 0]</td>
<td>![Image of Level 0]</td>
<td>![Image of Level 0]</td>
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<tr>
<td>1</td>
<td>![Image of Level 1]</td>
<td>![Image of Level 1]</td>
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<td>![Image of Level 1]</td>
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</table>

Six different levels of autonomy (zero to five)

- **Level 0**: No advanced driver assistance system (ADAS)
- **Level 1 – 3**: Semi-automated
- **Level 4 – 5**: Fully Automated

*Society of Automotive Engineers. Copyright © 2018 by Standard & Poor’s Financial Services LLC. All rights reserved.*

*S&P Global Ratings*
Industry Disruptors:

• Advent of Autonomous Vehicles and Implications for Transportation Infrastructure

  • Automated-to-Autonomous vehicles (AVs) will ultimately be as transformative as other historic mobility advances including the locomotive and the automobile. Consumers, regulators and infrastructure providers will face profound challenges and opportunities in preparing for the reality of AVs.

  • No one knows yet precisely what the impacts will be. Timing and magnitude of impact on future travel patterns depends on the following:

    1. **Technological readiness.** Widespread deployment of driverless technology is inevitable. But vehicle innovation may outpace the infrastructure needed to deploy AV. For example, a tepid response in building dedicated “smart” infrastructure for AV travel, vehicle-to-infrastructure and vehicle-to-vehicle communication may drag on penetration.

    2. **Customer adoption.** Replacement of existing vehicle fleet has been historically predictable, and would allow for a potentially gradual transition to AV. But accelerated purchase rates could upend this. Demand for private cars may shift from an ownership to a subscriber model of vehicle-sharing.

    3. **Regulatory acceptance.** Regulatory obstacles may impede market entry and deployment, and shape regional transport investment and system enhancements.

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Some fully autonomous vehicles are likely to be commercially available by 2022.

1 out of 10 new cars sold in 2030 may likely be a shared vehicle.

Up to 20% of new cars sold in 2035 could be fully autonomous.
The Infrastructure Funding Model Will Need To Evolve

Infrastructure funding model will need to evolve:

**State and Local:** How will the public sector replace an estimated $251 billion in annual gas taxes, transit fares, tolls, vehicle sales taxes, municipal parking, and registration and licensing fees linked directly to the current model of personal car ownership?

Note: started to include as a credit impact but it is mentioned in other slides within the presentation.
Autonomous Vehicles Preliminary Views

Fluidity of factors on pooling and AV makes predictions uncertain*

- Higher VMT due to increased mobility from current non-drivers coupled with an aging population (+)
- Fewer road delays due to safer highway travel (+)
- Increased carrying capacity due to more efficient driving patterns (+)

- Revival of commercial trucking industry due to AV technology (+)
- Increased lane throughput due to platooning (+)
- Smart-car technology may improve electronic-toll collection methods (+)
- Reduced congestion due to increased off-peak and overnight driving (-)
- Greater road wear and tear (-)

- Reduced personal vehicle ownership (-)
- Increased car-sharing (-)
- Reduced need for on-site parking(-)
- Development of new areas / land for off-site parking, maintenance and storage of fleet-wide AVs (+)

- Development of dedicated lanes for AVs (+)
- Increased carrying capacity in non-managed lanes (-)
- Reduction in revenues due to free lane usage for HOVs (-)
- Reduced congestion due to increased off-peak and overnight driving (-)
- Reduced vehicles on the road due to pooling (-)

*We are not currently rating to this view on winners and losers (which assumes full automation which is a ways off). But we expect to begin to incorporate stress scenarios into our financial forecast analysis to assess asset resiliency.
Possible Impacts for Infrastructure Assets
(assuming transition to full adoption)

• Vehicle miles travelled (VMT) - Increases in Near Term
  ↑ Increased convenience and productivity gains, induced demand from current non-drivers, potential substitution from mass transit/train/air, facilitated pooling, traffic management to curb excessive demand, commercial transport becomes more competitive

• Congestion - Uncertain
  ↑ Increased trip-making and with more miles traveled
  ↓ Safety improvements leading to less ‘driver error’ related accidents, ride sharing, platooning capabilities make roadways more efficient, smarter routing, quicker reaction times, increased off-peak travel

• Parking requirements - Decreases in Long Term
  ↓ Reduced vehicle ownership, increased car sharing can reduced need for on-site parking
  ↓ Impacting governments and airport operators

• Public transport - Decreases in Long Term Outside of Urban Core
  ↓ Displace passenger rail and air travel between short haul destinations

• Road lifecycle costs - Uncertain
  ↑ Increased volume of traffic, greater wear and tear due to more commercial vehicles on the road
  ↓ Smoother braking and acceleration of AVs could potentially offset the additional roadway wear and tear, but is highly dependent on market penetration of AVs